ARI Research Note 95-33

Effects of Personnel Turbulence on Tank Crew Gunnery Performance: A Review of the Literature

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April 1995

United States Army
Research Institute for the Behavioral and Social Sciences

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency Under the Jurisdiction of the Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Director

Research accomplished under contract
for the Department of the Army

BDM Federal, Inc.

Technical review by

J. Douglas Dressel

Accesion For	
NTIS CRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution /	
Availability Codes	
Dist	Avail and / or Special
A-1	

NOTICES

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
1995, April

3. REPORT TYPE AND DATES COVERED
Final Jun 93 - Feb 95

4. TITLE AND SUBTITLE
Effects of Personnel Turbulence on Tank Crew Gunnery Performance: A Review of the Literature

5. FUNDING NUMBERS
MDA903-92-D-0075
63007A
793
2125
C02

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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1801 Randolph Road, S.E.
Albuquerque, NM 87106

8. PERFORMING ORGANIZATION REPORT NUMBER

--

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Institute for the Behavioral and Social Sciences
ATTN: PERI-ID
5001 Eisenhower Avenue
Alexandria, VA 22333-5600

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

ARI Research Note 95-33

11. SUPPLEMENTARY NOTES
This research was performed by subcontractor PRC, Inc., to BDM Federal, Inc. Contracting Officer's Representative, Joseph Hagman.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release;
distribution is unlimited.

12b. DISTRIBUTION CODE

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13. ABSTRACT *(Maximum 200 words)*

This literature review summarizes studies that examined the effects of personnel turnover and turbulence on tank crew gunnery performance. This literature is compared and contrasted to literature on the performance of flight crews. The findings appear to contradict a widely held belief that it is important to stabilize tank crews during their training. If tank crews are formed of personnel who are skilled in the performance of their duty position tasks, they do not have to be familiar with each other to perform effectively. The flight crew literature suggests that there may be a brief initial period during which performance is reduced, but the length of this period is not well estimated in any of the published studies. Both literatures indicate that there may be reductions in performance if crews are kept intact over too long a period. Again, the point at which this effect takes place and the rate of decline are not well estimated in the literature. Training managers are advised not to take extra pains to maintain intact crews. Suggestions for further research are also given.

14. SUBJECT TERMS
Reserve Component
Armor training
Tank gunnery
Turbulence

15. NUMBER OF PAGES
28

16. PRICE CODE
--

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

EFFECTS OF PERSONNEL TURBULENCE ON TANK CREW GUNNERY PERFORMANCE: A REVIEW OF THE LITERATURE

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EFFECTS OF PERSONNEL TURBULENCE ON TANK CREW GUNNERY PERFORMANCE: A REVIEW OF THE LITERATURE

Background

U.S. Army National Guard (ARNG) tank crews are expected to qualify annually on tank gunnery Table VIII, which assesses the skill of the crew in simulated engagements firing live rounds at pop-up targets. The crew must maneuver its vehicle from location to location and destroy the enemy targets. Time and accuracy factors are weighted to form a total score, as described in FM 17-12-1 (Department of the Army, 1988a).

Table VIII is a training gate that crews must pass before they may go on to gunnery combat tables involving sections (two tanks) and platoons (four tanks). In order to perform the more advanced section and platoon training that will make the battalion combat effective, it must maintain the proficiency levels of crews with respect to Table VIII.

Impediments to tank combat table training must be identified and eliminated to make the training more effective and efficient. Eisley and Viner (1988, 1989) have documented the training challenges facing ARNG armor units: geographical dispersion, restricted access to maneuver areas and ranges, and limited training time. The limitation on training time is especially constraining: there are 12 Inactive Duty Training (IDT) weekends and a 2-week Annual Training (AT) period each year (U.S. Army Training Board, 1987).

Tank crew performance is regarded as requiring a high degree of interaction among the crew members. Kahan, Webb, Shavelson, and Stolzenberg (1985) distinguish interactive from coactive tasks by noting that for coactive tasks the group goal is accomplished by having each individual perform his task(s) more or less independently of the performance of others. Interactive tasks require individuals to coordinate activities extensively in order to attain the group goal. Kahan et al. (1985) rely on a sports analogy to clarify this distinction: A succession of batters in baseball perform coactive tasks (each batter tries to get on base because that will help to produce runs) while a football team is interactive (on each down, all team members work together, adaptively coordinating performance of their individual tasks to move the ball down field).

Eaton and Black (1980) describe the nature of coordination among tank crew members in this way:

> Each duty position within the tank system requires unique skills and smooth coordination with the other crew members. The TC (tank commander) must identify and range on targets, communicate his findings to the gunner and loader, and be prepared to guide the driver through difficult terrain based solely on voice commands.
>
> The gunner's response to the TC's identification of a target must be coordinated with the loader's response to the TC's command specifying the type of ammunition to be loaded. The accurate synchronization of these duties is essential. (p. 10)

Compounding the problem of limited training time within the ARNG is turnover and turbulence of crew personnel. Over time crew members will leave their assigned positions because they leave the unit (turnover), or because they are given a new assignment within the unit (turbulence).[1] Each time a new member joins a crew, some relearning of crew skills must take place to make sure that the newly constituted group can coordinate its activities effectively.[2]

Given the limited time available to train, if some part of the time must be spent retraining crew skills because of turbulence, then the overall effectiveness of training will be diminished. Units experiencing less turbulence should be able to attain a higher degree of effectiveness than those experiencing more turbulence.

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[1]As turnover implies some degree of turbulence, the more general term turbulence will be used throughout this report to indicate that crew composition is changing, whatever the underlying reason. The term stability is used as an antonym for turbulence, i.e., that crew composition is not changing.

[2]The <u>Principle of Training</u>, <u>Train to Sustain Performance</u>, addresses the need to retrain as a function of turnover and turbulence in personnel (Department of the Army, 1988b).

In order to plan training programs that will be least disrupted by crew turbulence, ARNG armor unit trainers must have some idea of the impact turbulence has on performance. This report examines the literature discussing the relationship between crew turbulence and performance. Implications for training planning, as well as directions for further research, are derived.

Method

A literature review was conducted to identify reports describing the relationship between stability of groups and their performance. This search extended beyond the Army to the other military services and to civilian settings. Reports concerning aviation crews seemed most relevant.[3] Selected reports were examined in greater detail, and authors were contacted in order to determine if there were additional research results of interest.

The results section summarizes two areas represented in the literature:

- The effects of stability on performance of flight crews
- The relationship of stability to performance of tank crews.

The discussion section contrasts the literature on tank crews to that on flight crews. Some general conclusions about the influence of turbulence on performance are reached and the implications for designing training programs are explored. Some guidance for further research in this area is also provided.

Results

Results are presented in two subsections: research on flight crews and research on tank crews.

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[3]Reeves (1982) and Dropp (1989) were the only studies identified concerning Navy vessels. They reported that turnover did not seem to influence ship performance.

Research on Flight Crews

Branches of the Navy and Air Force differ on the degree to which they consider it important to maintain the stability of flight crews. Historically, the Air Force has distinguished between strategic, logistic and tactical roles for aircraft. In the past, the Strategic Air Command emphasized stable flight crews (called "fixed" crews), while the Military Airlift Command (logistic emphasis) did not, preferring to assign "formed" crews for each mission. A recent study (Woody, McKinney, Barker, & Clothier, 1994) found that the formed crews had 40-60% fewer accidents per sortie. This result led to the hypothesis that complacency or inattention afflicted the more stable fixed crews. Unfortunately, the amount of time crews had been together was not collected in this study. In a follow-up study using simulators rather than real flights, it was found that both fixed and formed crews were similar with respect to major errors, but the formed crews made fewer minor errors (Colonel J. Woody, personal communication, October, 1994).

No published literature could be found that examined the relationship of stability of flight crews to performance for the U.S. Navy. Personal communications with researchers indicated that the Navy traditionally attempts to protect the integrity of two-person fighter (e.g., F-14) crews when one is the pilot and the other operates radar and jamming equipment. Certain Navy helicopter crews, however, have two pilots who have equal training and who can fly the craft from either physical position in the cockpit. No attempt is made to stabilize these crews.

The EA-6B electronic warfare platform is flown by a four-person crew. Personal contacts with pilots of these craft indicated that the degree to which crews are stabilized depends upon the commanding officer. Some make fixed assignments, while others form new crews for each mission. These personal contacts indicated that even when the assignments are fixed it is typical that 40% of the sorties flown by fixed crews involved one person who was not part of the assigned crew. One person contacted for information about the Navy indicated that maintaining intact crews was a scheduling nightmare when they were land based, but much easier to do when at sea (Dr. C. Prince, personal communication, October, 1994).

Civilian flight crews are characterized by considerable turbulence. A typical Boeing-727 crew consists of a Captain, a First Officer, and a Second Officer or Flight Engineer.[4] Each is trained to be in command of a flight. Each month each airline publishes a list of the flights it will fly in the upcoming month and the crew members bid for the flights they want. Flights are awarded on the basis of seniority. A person who may qualify to be in the Captain's chair flying out of one location, may prefer to fly as a First Officer from another location (closer to home, for example). In principle, the composition of the crews could change each month. However, there is some tendency to repeat assignments from month to month. The author was unable to identify a study that specifically examined the normative amount of crew turbulence.

Studies of civilian crews seem to focus on safety as the primary performance outcome of interest. Two studies are particularly germane to this review. One shows that relatively short periods of working together seem to lower the rate of serious crew errors. The other found that crew-involved accidents were most likely to occur on the first day a crew was together.

Foushee, Lauber, Baetge, and Acomb (1986) used highly realistic simulated flights as a testing ground to examine effects of fatigue on crew performance. They formed 11, two-person crews from personnel that had been on leave for 2-3 days and compared them to 9, two-person crews formed from personnel that been through a relatively intense working period of 3 days (flying short-haul segments, including 1 day that involved eight such segments). Although the latter group of crews reported much higher levels of fatigue, they were much less likely to commit serious errors than the rested crews. Closer examination of the data revealed that most of the fatigued crews were intact crews that came together to the simulation facility, while the others were largely formed of personnel that had not worked together in the previous month. When the crews were segregated based on whether or not they had worked together, the outcome measures clearly indicated that crews that had worked together in the previous period performed better than crews that had not. It is

[4]Boeing-737 crews consist of a Captain and a First Officer.

important to note that many of the personnel who had not worked together in the most recent period had worked together before, so recency of experience was deemed an important factor in determining the outcome.

The National Transportation Safety Board (1994) examined crew familiarity as a possible causal factor in 37 flightcrew-involved accidents (accumulated over a 12-year span). In 73% of the accidents for which data were available (n = 15), the accident occurred on the first day the crew was together. This reinforces the notion that a crew must have some time together to develop an effective pattern of communication.

Foushee (1984), Chidester (1990), and the Federal Aviation Administration (FAA) (1993) all indicate that training in Crew Resource Management (CRM) is a valid way to assist crews to develop effective communication, balance workload requirements, and optimize performance in stressful circumstances. However valuable this training may be, compliance with the FAA guidance on CRM training is not mandatory.

<u>Summary</u>: The flight crew literature indicates that a newly formed crew needs time to establish effective communication, that crews that have been together for just a few days seem to be effective, and that crews that have been together for longer periods of time seem to experience degradations in performance. The research literature does not indicate precisely how much time each of these stages takes. It appears that the required period of familiarization may be fairly short, but the time to reach peak performance, and the duration of that level of performance, are not estimable from the data in the literature.

The flight crew literature does not address training of Captains and First Officers. It indicates that crews may be readily formed of personnel who are proficient at their tasks. It does not clarify whether or not maintaining a fixed crew during training is important for achieving proficiency.

Although each flight crew involves at least a Captain and a First Officer, each is capable of flying the aircraft. They are

encouraged to question each other on the nature of their performance.[5]

Tank crews have a more rigid hierarchy of roles, and subordinates to the TC typically are not qualified to take on his role. Similarly, drivers, loaders and gunners are not necessarily prepared to substitute for each other. These differences in the ability to balance workload imply that the role of communication within the tank may be different from its role within the cockpit.

Research on Tank Crews

The research on tank crews is divided into two sections. The first examines the degree to which tank crews are stabilized while the second examines the relationship of crew stability to performance on tank gunnery Table VIII.

How stable are tank crews? Table 1 shows the data available from several published studies. The studies used differing measures of stability, but whatever the metric, most show rather low amounts of stability. The results from Keesling, Ford, O'Mara, McFann, and Holz (1992) may indicate that crews are more stabilized in months prior to a training rotation at the National Training Center (NTC) than they are in months prior to a Table VIII exercise. Thirty-seven percent of the crews (n = 133) in this study were from COHORT (Cohesion, Operational Readiness, and Training) battalions and had median TC/gunner stabilities in excess of 6 months. The lowest median stability reported in this study was 3 months, for a non-COHORT battalion that was chronically under strength and made many personnel changes to accommodate closing down one company.

One of the non-COHORT brigades in this study was able to attain a median of 6 months of TC/gunner pair stability (across two rotations separated by 11 months). The division commander required that any proposed change to crew composition had to be

[5]This was not always the case. Foushee (1984) states that guidelines for one major airline in 1952 said that the First Officer should not correct pilot errors.

approved by the battalion commander. Apparently, this directive had the effect of dampening turbulence.

Table 1.

Stability of Tank Commander/Gunner Pairs

Source	Number of Crews	CONUS or USAREUR	Median Months Assigned Together	Percentage Together for 6 or more months	Event at end of time period studied
Eaton and Neff (1978)	211	USAREUR	2.6		Table VIII
Campshure and Witmer (1989)	68	CONUS	3[a]		Table VIII
Campshure and Drucker (1990):					
Phase I	77	CONUS	3	25%	Table VIII
Phase II	129	CONUS	2	22%	Table VIII
Keesling, et al. (1992)	361	CONUS	5	49%	NTC rotation
7th ATC (ca 1992)	371	USAREUR		29%	Table VIII

Note. CONUS = Continental United States; USAREUR = US Army Europe; ATC = Army Training Command.
[a]Estimated from data summaries in Campshure and Witmer (1989).

The studies in Table 1 all examined Active Component crews, and it is difficult to project their results onto ARNG crews. Training in the ARNG is spread out over longer periods of time, so the equivalent of 3 months together in the Active Component could be a year or more in the ARNG. If turnover and turbulence occur at the same rates in the ARNG as they do in the Active Component, it might be very difficult to stabilize TC/gunner pairs for the equivalent amount of exposure to training.

How is crew experience related to Table VIII performance? Table 2 summarizes the data from several studies involving Active Component units. The data show that crew experience is not related to Table VIII performance. The values reported are either the square of the zero-order correlation coefficient, or the contribution to the multiple R^2 made by the crew experience measure when combined with other predictors. Each of these values estimates the proportion of variance in the performance measure accounted for by the measure of experience.

The measures of experience were not identical across the studies. Most used the number of months the TC or gunner had been in the duty position, and the number of months the TC and gunner had served together on the same crew.

Eaton and Neff (1978) administered a survey that asked crew members to report the number of months the TC (or gunner) had trained at that position and how long the crew had trained together in addition to information about length of assignments to the duty position and crew. They reported that while TC/gunner pairs had been assigned together for 2.6 months (median value, see Table 1), they had trained together for 1.9 months (median value). The months they were assigned together did not relate to the performance measures, while the months they trained together did.

Hoffman (1989) reported that a quadratic component of experience was related to performance. The form of the quadratic relationship indicated that performance improved from very low levels of experience to some middle value, then either leveled off or degraded. Hoffman (1989) fitted other models that allowed performance to reach a limiting value, then remain stable. These models seemed to fit relatively well and indicated that 6 months

Table 2.

Variance in Tank Table VIII Performance Accounted for by Crew Member Experience

Performance Measure:	Engagement Scores			Opening Time			Accuracy (% hits)		
Experience of:	TC	Gunner	TC+Gunner	TC	Gunner	TC+Gunner	TC	Gunner	TC+Gunner
Eaton and Neff (1978) 184 ≤N ≤211				.05	.00 (-) ns	.04	.00 (-) ns	.00 ns	.00 ns
Baldwin and Scribner (1985) N = 615	.00[a] ns	.01[a]							
Hoffman (1989) N = 800+	.01	.00 ns		.00	.01		.00 ns	.00 ns	
Campshure and Drucker (1990): Phase I N = 77			.01 (-) ns			.01 (-) ns			.00 (-) ns
Phase II N = 129			.05						

Note. N = number of crews in study. Experience was negatively related to performance in studies noted (-). All studies but Campshure and Drucker (1990) used USAREUR crews. All relationships were statistically significant ($p < .05$), except those marked ns.

[a]Estimated from Table 2 of Baldwin and Scribner (1985).

of experience was needed to attain the best performance. Smith and Hagman (1992), dealing with ARNG soldiers who are probably older than their Active Component counterparts and whose training is not as intensive, also reported a quadratic relationship between the average of the TC and gunner years of military service and Conduct-of-Fire Trainer (COFT) hit rate scores. They found that an average of 9 or 10 years of service was needed to reach optimum performance levels, which then degraded with additional years of service. This study did not examine the amount of time the TC and gunner had trained together.

Better measures of training received by the TC, the gunner, and by the pair together, are needed to examine the effects of experience on performance. The rapid forgetting rate of armor skills (Knerr, Harris, O'Brien, Sticha, & Goldberg, 1984) suggests that training experiences in a relatively short period before Table VIII may be the most important to capture.

Table 2 shows that accuracy is poorly predicted by measures of TC and gunner experience. Accuracy is likely to depend largely on the perceptual and psychomotor skills of the person firing the weapon. If these skills degrade beyond a certain point, then crew performance on Table VIII will be affected. Smith and Hagman (1992) report that among a sample of ARNG crews TC vision was related to Table VIII performance, and that older gunners were "the kiss of death" (p. 40). Black and Graham (1987) indicate that visual acuity is a likely component of Table VIII performance, and Graham (1989) shows that spatial and psychomotor tests are strong predictors of speed and accuracy measures on the COFT.

Table 2 shows that the contribution that experience of the TC and gunner make to prediction of Table VIII opening times (the time from target presentation to first firing) and engagement scores is modest, at best. One possible problem with the research summarized in Table 2 is the use of time in position as a surrogate for experience. If recency of experience is more important that the accumulation of experience, then the experience gained during the most recent training prior to Table VIII may be the most important. If Table VIII is the culmination of a relatively short, but intensive, period of training (in both the ARNG and the Active Component), then individuals and crews that were together for that training may be equally prepared for

Table VIII, even though some have been in the duty position longer than others, and some crews have worked together longer than others. Eaton and Neff's finding (1978) that the amount of time trained together was related to performance, while the amount of time assigned together was not, reinforces the need to better measure training experiences, not merely time together.

The empirical data summarized in Table 2 do not substantiate a need to stabilize TC/gunner pairs in order to perform well on tank gunnery Table VIII. Generally speaking, the amount that crew time together contributes is very small, and may be entirely explained by the training experiences of the individuals, rather than the amount of time the crew has been stable.

In the first phase of their study, Campshure and Drucker (1990) found the experience of the TC/gunner pair working together was negatively related to performance, while in the second phase (with a different sample of crews) the relationship was positive. Since earlier studies showed that the experience levels of the TC or gunner as individual crew members were important, they should have incorporated such measures and conducted an analysis to determine whether TC and gunner time together improved on predictions made using the individual experience variables.

Eaton and Neff (1978) collected the data needed to examine the contribution of training the TC and gunner together over and above their individual training, but they did not do this analysis. Their summary data are not complete enough to allow a secondary analysis of this nature. It is quite possible that the TC training variable would account for much of the relationship of crew training to performance shown in Table 2.

In a follow-up experiment conducted with CONUS crews, Eaton and Neff (1978) compared crews made up of personnel who had not been assigned to the same crew previously to intact crews that had trained together. All personnel had just completed gunnery training that culminated in Table VIII. Eaton and Neff re-arranged 10 of these crews to create new crews that had not trained together (all four positions were filled by personnel not familiar with each other). A second Table VIII was run and the 10 new crews performed as well or better than 11 crews that were

retained intact. This result indicates that the time trained together is not an important predictor of Table VIII performance.

Results from a third group of crews created by Eaton and Neff (1978) further reinforce the notion that the time the TC and gunner train together is not particularly important. In these 10 crews the TC and driver were from (different) crews that had completed the first Table VIII exercise. The gunner and loader were nonarmor personnel who went through an intensive 3-day training program (with a different TC and driver). This group of 10 crews also performed as well as the two groups described above. This result indicates that it is the proficiency of the individuals rather than the time the TC and gunner have been together that makes the difference in Table VIII performance.

Eaton and Neff (1978) also created a fourth group of crews in which none of the personnel had previously worked together. In these crews the TC position was filled by a gunner, and the gunner position was filled by a loader, each of whom had been through the prior Table VIII exercise. The loader and driver were taken from other crews that had also been through that exercise. The new TC and gunner had received classroom-based cross-training in their new positions, but had not received hands-on cross-training. Of the 11 crews created under these conditions, 2 were disqualified during the second Table VIII for safety-related reasons, and the other 9 performed significantly worse than the intact crews. This result reinforces the conclusion that individual proficiency in a duty position is critical for Table VIII success.

Summary. Research on tank crews indicates that there is a good deal of turbulence in Active Component crews (up to Table VIII; they may be more stable prior to an NTC rotation). COHORT units are more stable than most non-COHORT units, although it appears that high-level directives may be enough to increase stability of non-COHORT units considerably.[6] The research also indicates that crews composed of members who know their duty position skills, but who are not familiar with each other, will perform well on Table VIII. The key to training success appears

[6]ARNG does not have COHORT units, so these findings may only apply to ARNG crews that are relatively stable over time.

to be to train the individuals to perform their duty position skills. The key to further research appears to be to obtain better measures of the training experiences of the crew members.

Discussion

The discussion section is in three parts. The first compares and contrasts the flight crew research and the tank crew research presented above. The second discusses some implications of the research summarized above for the conduct of training. The third describes research that could be done to further improve training efficiency and effectiveness.

Comparing and Contrasting Research on Tank Crews and Flight Crews.

The research on flight crews indicated that well trained crew members could be combined into new crews effectively. One important study indicated that there might be a brief period of lesser effectiveness (the first day together seemed to have a disproportionate number of major accidents). The data on tank crews also indicated that crews may be made up of trained personnel who are unfamiliar with each other. No mention was made in the tank crew literature about a critical period of familiarization.

Research on flight crews indicated that there may be a time beyond which a fixed (stable) crew is no longer as effective as a newly formed crew. This effect was not directly identified in the tank crew literature. There were implications that the gunner's time in duty position might bear a curvilinear relationship to performance, or that overall time in service might be quadratically related to performance. Neither the flight crew literature nor the tank crew literature has systematically explored the hypothesis of curvilinear relationships to identify the range of stability or experience that leads to near-peak performance, and the degree to which additional stability, age, or experience detracts from that level of performance.

The implication for the training and composition of tank crews seem to be that crews may be composed of individuals who are unfamiliar with each other, as long as they are competent at

their duty position tasks. Further research should examine whether an initial period of familiarization is required to optimize performance of newly constituted crews, and whether continued stability of crews eventually leads to degraded performance (above and beyond that due to aging effects).

Designing Training Programs to Cope with Turbulence.

The research summarized above shows that there is considerable turbulence in armor crews. There are two approaches to dealing with this phenomenon:

- minimizing the amount of turbulence, or
- minimizing the effects of turbulence.

Minimizing the amount of turbulence. The Keesling, et al. (1992) data (see Table 1 and related text) illustrate that a directive from a high-level command can have the effect of reducing crew turbulence.

The same technique may be applicable to ARNG units. The contractor developing a time-compressed, technology-based tank gunnery training strategy for the ARNG (see Morrison & Hagman, 1994) indicated that the commander of the ARNG battalion assisting in this development had issued a similar directive and that turbulence had been greatly reduced (personal communication, J. Morrison, October, 1994). Clearly, turbulence cannot be eliminated entirely because some personnel will leave the community and will have to be replaced. However, turbulence appears to have such a small effect on performance that it may not be worth trying to stabilize crews.

Minimizing the effects of turbulence. The research summarized above does not implicate turbulence as a major cause of low performance by tank crews on Table VIII. The important element of training is providing crew members with adequate opportunities to learn the individual skills associated with their duty positions. Furthermore, substantial cross-training must be provided if it is anticipated that crew members will have to replace others who become casualties.

Training managers will need to maintain a battle roster of tank crews, and may focus on training those crews as intact entities; but, they need to be able to flexibly re-assign personnel to accommodate turnover and turbulence, to allow for promotions, and to reconstitute crews if, for whatever reason, a particular crew does not seem to learn at the appropriate rate. In addition, ARNG training managers need to be able to re-assign personnel each training weekend to optimize the training opportunities for all personnel.

The newly developed, time-compressed training program (Morrison & Hagman, 1994) focuses on remediating crews that are experiencing difficulties mastering the skills needed for Tank Gunnery Table VIII. Prior research indicates that the problem is not in training intact crews, but training the individuals to perform the tasks associated with their duty positions. Training managers need to be sure that a focus on training/remediating intact crews does not lead them to deny personnel valuable training opportunities because a member of their crew happens to be absent for a drill weekend.

The training program proposed by Drucker (1991) could be used to train individuals when one or more crew members are absent. Or, the crew members could be paired with personnel from other crews to use the COFT or GUARDFIST I (Guard Unit Armory Device, Full-Crew Interactive Simulation Trainer - Armor) for training in their duty positions, or for cross-training.

The 3-day intensive training program for gunners and loaders described by Eaton and Neff (1978)[7] could be adapted to the ARNG setting if it became important to train new gunners and loaders rapidly.

Arguably, the most important position on the tank is that of the TC. Training managers need to focus on having a cadre of capable TCs. There may be a need to develop some training aids, devices, simulations and simulators (TADSS) for TCs to use by themselves. Beginner TCs just acquiring the skills might have

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[7]More detailed descriptions may be found in O'Brien, Crum, and Healy (1978).

different training needs than established TCs who need to sustain their skills, while some TADSS might apply to both groups.

As the time to run Table VIII approaches, crews could focus on activities that would prepare them for the particular Table VIII engagements that they are most likely to find difficult. Hagman (1994) examined the performance of ARNG crews on an instrumented range and identified some exercises that were particularly difficult in that setting. Hoffman (1989), working with Active Component crews on a standard range, found a similar ordering of engagement difficulties, but would have identified a somewhat different selection as the most difficult.[8]

Further Research Needed on the Effects of Turbulence

Chidester (1990) presents the case that there are three main lines of research that will improve crew performance:

- identification of personal characteristics that relate to performance
- identification of training strategies that improve performance
- identification of ways to modify tasks to enhance crew performance.

Several of the articles referenced in the literature review summarized above also mentioned personal characteristics related to performance: Ability (as measured by the Armed Forces Qualification Test [AFQT]), age (represented by time in service), visual acuity and psychomotor abilities were identified as possible predictors of tank gunnery performance. Tziner and Eden (1985) showed that motivation and ability of individual crew members were strongly related to performance (of Israeli tank crews) when the time the crew spent together was equalized by their experimental procedures. These individual difference variables should be accounted for in future research. Knowing

[8]The instrumented range may have made certain engagements more difficult (e.g., machine guns must hit targets, not merely suppress them).

how they relate to performance will make it possible to optimize selection criteria for armor crews.

In addition to identifying ability as a predictor of tank gunnery performance, Scribner, Smith, Baldwin, and Phillips (1984) also indicated that the M1 (compared to the M60) tank appeared to be designed to facilitate crew performance. Further research could pursue ways in which the equipment or the tasking could be modified to facilitate performance. Basic research might investigate the nature of the communication within the tank. Are most communications highly routinized, such as commands to load and fire the weapons? Can these be improved upon? The flight crew studies identified confirmation that a message or command had been received as an important component of crew coordination. Are there intratank communications that involve information sharing, coordination, and decision making that require better training in stating and confirming receipt of messages?

Specific research on the effects of turbulence needs to be aimed at examining the value added to training of individual skills by training intact crews. Measurement issues involve quantifying the amount of training each crew member has received and the proficiency of each crew member with respect to his duty position tasks. Once these factors, as well as ability and other personal characteristics are accounted for, then the value added by the amount of stability of the crew can be assessed.

It should be possible to capture the training of individuals by examining training records maintained in armories. However, in a related project aimed at initiating a training database for the ARNG it was discovered that there is a wide variety of record keeping formats and that much of this information is not automated, making it exceedingly inefficient to gather the data. (Keesling & Clifton, 1994; Clifton, 1994). TADSS need to incorporate measures of individual and crew performance, but they do not routinely do so, as Black and Graham (1987) noted about the COFT.

The effects of turbulence could be examined experimentally by allocating crews to two treatment conditions: Some crews would be stabilized for an entire training period leading to Table VIII while other crews would be reconstituted on a periodic

basis. The prior research would lead to the expectation that, as long as individuals in the two types of crews received the same amount of training at their Table VIII duty position skills, the two types of crews would perform identically. If it became clear during the course of the experiment that one or the other type of crew composition (stable or turbulent) was leading to diminished amounts of training in the individual skills, then the experiment could be halted so that the crews in the detrimental condition could be reassigned to the better condition.

As far as outcome measures are concerned, the first-run scores on Table VIII seem to be most appropriate. When the focus is on qualification, a binary variable representing whether or not a crew qualified on the first run could be used in a logistic regression paradigm. Another way to examine qualification issues would be to look at the resources required to qualify a crew: counting the number of main gun rounds fired on Table VIII, or the number of total engagements fired to attain qualification. Crews that don't qualify on the first run will have higher numbers of engagements attempted, and may have higher counts of rounds fired.

The finding that continued stability of crews may be detrimental to performance merits further investigation. In the ARNG setting it may be difficult to conduct such an investigation because crews might be expected to rapidly lose their Table VIII skills due to forgetting, then experience a long period of re-learning prior to the next AT Table VIII gunnery. These effects might overwhelm a subtle trend to diminished performance due to crew stability. A longitudinal database might be able to track successive Table VIII performances for intact crews over a sufficiently long period to enable identification of the point at which continued stability becomes detrimental.

Summary

Literature on flight crews and tank crews indicates that crews may be composed of personnel who have no previous familiarity with each other, as long as the individuals are competent in the skills associated with their duty positions. There may be a brief period needed to establish an effective pattern of crew interaction. Continued stability over time may eventually lead to deterioration of performance. It is not clear

how long any of these phases last: the initial time to develop effective crew interaction, the period of effective performance, and the period (and rate) of decline in performance.

Training managers need to be able to flexibly assign personnel to crews, and the research literature does not argue against this policy. Crew stability is not an important predictor of crew performance.

The value added by crew stability needs to be examined in a more rigorous program of research which accounts for individual difference variables (e.g., ability, psychomotor skill, visual acuity) and individual competence in duty position skills.

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